[0019] In a preferred embodiment, the magnetically-controllable medium within the magnetically-controllable device is contained by an absorbent element disposed between the first and second member. The absorbent element may be compressed from a resting state, preferably in the amount of about 30%-70% of the resting state. The absorbent element may be formed as a matrix structure having open spaces for retaining the magnetically-controllable medium. Suitable materials for the absorbent element comprise open-celled foam, such as from a polyurethane material, among others.

[0020] The magnetically-controllable medium is a medium having a shear strength that varies in response to the strength of an applied magnetic field. One preferred type of magnetically-controllable medium is a magnetorheological fluid. As mentioned above, the magnetic-field generating device provides the applied magnetic field. The magnetic-field generating device is preferably a coil and comprises a wire having a number of turns and a certain gauge. The number of turns and gauge of the wire are dependent upon the desired range of the variable strength magnetic field and upon the electric current and voltage of the variable output signal.

[0021] As previously indicated hereinabove, the controller may comprise a computer system further comprising a host computer, a control unit and an amplifier. The control unit and amplifier, as is explained below, may alternatively be separate components or part of a haptic interface unit. The host computer comprises a processor that runs the interactive program. The control unit comprises a microprocessor and firmware that are used to modify the variable input signal received from the sensor and the variable output signal received from the host computer. The control unit then provides a modified variable input signal to the host computer and a modified variable output signal to the magnetically-controllable device. The modification function performed by the control unit enables communication between the host computer and the magnetically-controllable device and the sensor. The amplifier further modifies the output signal to provide an amplified variable output signal in situations where the output signal from host computer is not sufficient to control the magnetically-controllable device. Further, the control unit and amplifier may act as local processors, reducing the burden on the host computer by providing output signals for certain input signals, such as to provide reflex-like resistance forces, that do not need to be processed by the host computer.

[0022] In one embodiment, the present invention discloses a haptic interface unit comprising the magnetically-controllable device, as described above, is adapted to provide a variable resistance force in proportion to a received variable output signal generated by a computer system processing an interactive program. The magnetically-controllable device further comprises a magnetic-field generating device, first and second members, and a magnetically-controllable medium. The magnetic-field generating device is energizable by the variable output signal to provide a variable strength magnetic field. The first and second members are adjacent to the magnetic field generating device. The magnetically-controllable medium is disposed between the first and second members, where the magnetically-controllable medium provides the variable resistance force in response to the variable strength magnetic field. Additionally, the haptic interface unit may further comprise a haptic interface device, adapted to be in operable contact with the operator, for controlling and responding to the interactive program. The haptic interface device is in communication with the magnetically-controllable device and has a plurality of positions, wherein an ease of movement of the haptic interface device among the plurality of positions is controlled by the variable resistance force. Finally, the haptic interface unit may further comprise a control unit that provides a signal to the magnetically-controllable device to control the variable resistance force.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] **FIG. 1A** is a schematic block representation of the haptic interface system according to the present invention.

[0024] **FIG. 1B** is a schematic block representation of a haptic interface system according to the present invention for use in a computer simulation application.

[0025] **FIG. 1C** is a schematic block representation of a haptic interface system according to the present invention for use in a vehicle or machine steering application.

[0026] **FIG. 1D** is a schematic block representation of a haptic interface system according to the present invention for use in a vehicle or machine joystick application.

[0027] FIGS. **2A-2B** are a perspective view and a cross-sectional view, respectively, of a typical magnetically-controllable device.

[0028] **FIG. 3** is a partial cross-sectional view of one embodiment of a haptic interface unit.

[0029] **FIG. 4***a* is a cross-sectional view along line **4-4** in **FIG. 3** of one embodiment of a magnetically-controllable device.

[0030] **FIG. 4***b* is a cross-sectional view of an alternate embodiment of a magnetically-controllable device.

[0031] **FIG. 5** is a partial cross-sectional rear view of another embodiment of a haptic interface unit, with some components removed for clarity, utilizing the magnetically-controllable device of **FIGS. 3 and 4**.

[0032] **FIG. 6** is a partial cross-sectional side view of the haptic interface unit of **FIG. 5**, with some components removed for clarity.

[0033] **FIG. 7***a* is a partial cross-sectional top view taken along line **7***a*-**7***a* of **FIG. 5**, with some components removed for clarity.

[0034] **FIG. 7***b* is a top view of the sensor which interconnects to the plates of **FIG. 7***a;*

[0035] **FIG. 8***a* is a perspective view of yet another embodiment of a haptic interface unit.

[0036] **FIG. 8***b* is a side view of the rack of **FIG. 8***a*.

[0037] **FIG. 9** is a side view of yet another embodiment of a magnetically-controllable device.

[0038] **FIG. 10** is a cross-sectional view along line **10-10** of the device in **FIG. 9**.

[0039] **FIG. 11** is a cross-sectional view of another embodiment of a magnetically-controllable device.